INDOOR AIR QUALITY ASSESSMENT

Worcester Fire Department, Engine 15
86 McKeon Road
Worcester, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Bureau of Environmental Health Assessment
Emergency Response/Indoor Air Quality Program
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Background/Introduction

At the request of Captain John Ford of the Worcester Fire Department (WFD), an indoor air quality assessment was conducted at the Engine 15 Fire Station (the station) at 86 McKeon Road, Worcester, Massachusetts by the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA). The request was prompted by occupant complaints of cold and flu-like symptoms.

On August 13, 2003, a visit was made to the station by Cory Holmes, an Environmental Analyst in BEHA's Emergency Response/Indoor Air Quality (ER/IAQ) program to conduct an indoor air quality assessment. Mr. Holmes was accompanied by Captain Ford during the assessment.

The station is a two-story red brick building that was constructed in 1994. The ground floor contains the engine bay, the watch room, the coatroom, a laundry room, storage rooms, boiler plant and a hose drying room. The second floor contains the bunkhouse (for overnight staff), locker room, weight room, office space and kitchen/lounge. Windows are openable throughout the building. The west side of the building has three garage doors for access to the engine bay. A stairwell connects the engine bay to the second floor. Fire poles with access to the engine bay are located in the second floor hallway.

Methods

Air tests for carbon dioxide, carbon monoxide (CO), temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor. Test results are listed in Table 1.

Results

The station is staffed 24 hours a day, seven days a week and has an employee population of approximately 8. The station is visited by up to 5 members of the public on a daily basis.

Discussion

Ventilation

It can be seen from the tables that the carbon dioxide levels were below 800 parts per million (ppm) in all areas surveyed, which indicates adequate air exchange by the ventilation system. Ventilation is provided by air handling units (AHUs) located in the attic and above ceiling tiles in the watch room. AHUs are connected to wall or ceiling mounted air diffusers by ducts (Picture 1). Return vents in hallways and common areas (Picture 2) draw air back to AHUs via ductwork. These systems were in operation during the assessment and are controlled via a computerized system by an off-site heating, ventilation and air conditioning (HVAC) firm.

Thermostats have fan settings of "on" and "auto" (Picture 3). All controls were set to the "auto" setting during the assessment. The automatic setting activates the HVAC system at a preset temperature. Once the thermostat reaches a preset temperature, the HVAC system is deactivated until the temperature drops below the heating set point. Therefore, no mechanical ventilation is provided until the thermostat re-activates the system.

A vehicle exhaust ventilation system is installed in the engine bay to remove carbon monoxide and other products of combustion; the system is described in detail under the Vehicle Exhaust portion of this report.

To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. The date of the last balancing of these systems was not available at the time of the assessment. It is recommended that HVAC systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994).

The Massachusetts Building Code requires a minimum ventilation rate of 20 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please see Appendix I.

Temperature readings were measured in a range of 70^{o} F to 78^{o} F, which were within the

BEHA recommended comfort range. The BEHA recommends that indoor air temperatures be maintained in a range of 70° F to 78° F in order to provide for the comfort of building occupants. A number of temperature complaints were reported at the station. Complaints result from lack of local control by WFD due to the computerized system. As discussed, the system is controlled by an off-site HVAC firm. During the assessment Captain Ford reported that station staff were in negotiations to gain local control over the system to maintain comfort. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

Relative humidity measurements ranged from 51 to 67 percent, which were above the BEHA recommended comfort guidelines in some areas. The BEHA recommends that indoor air relative humidity is comfortable in a range of 40 to 60 percent. While temperature is mainly a comfort issue, relative humidity in excess of 70 percent can provide an environment for mold and fungal growth (ASHRAE, 1989). During winter months outdoor relative humidity levels tend to drop. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a common problem during the heating season in the northern part of the United States.

Microbial/Moisture Concerns

The building has reportedly experienced problems with water penetration, most notably on the east side of the building. Along the wall of the engine bay and on the second floor in the day room, water leaks were evidenced by damaged plaster on walls, stained ceiling tiles, peeling paint and efflorescence (Pictures 4 & 5). Water-damaged ceiling tiles can provide a source of mold and should be replaced after a water leak is discovered and repaired. Efflorescence is a characteristic sign of water damage to building materials such as brick or plaster, but it is not mold growth. As moisture penetrates and works its way through mortar around brick, water-soluble compounds dissolve, creating a solution. As the solution moves to the surface of the brick or mortar, water evaporates, leaving behind white, powdery mineral deposits. This condition indicates that water from the exterior has penetrated into the building. In this case the most likely source of water penetration is from improper drainage along the roof where the engine bay meets the hose drying room, allowing water to seep down the side of the building (Pictures 6 & 7).

Another means for water penetration into the building was around window frames. Spaces were observed between windows and window frames (Picture 8). Repeated water damage to porous building materials (e.g. wallboard, ceiling tiles, carpeting) can result in microbial growth. The US Environmental Protection Agency and the American Conference of Governmental Industrial Hygienists (ACGIH) recommends that porous materials be dried with fans and heating within 24-48 hours of becoming wet (US EPA, 2001; ACGIH, 1989). If not dried within this time frame, mold growth may occur. Once mold has colonized porous materials, they are difficult to clean and should be removed.

Vehicle Exhaust

Under normal conditions, a firehouse can have several sources of environmental pollutants present from the operation of fire vehicles. These sources of pollutants can include:

- Vehicle exhaust containing carbon monoxide and soot;
- Vapors from diesel fuel, motor oil and other vehicle liquids which contain volatile organic compounds;
- Water vapor from drying hose equipment;
- Rubber odors from new vehicle tires; and

- Residues from fires on vehicles, hoses and fire-turnout gear.

The process of combustion produces a number of pollutants, depending on the composition of the material. In general, common combustion emissions can include carbon monoxide, carbon dioxide, water vapor and smoke. Of these materials, carbon monoxide can produce immediate, acute health effects upon exposure. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within the rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

The US Environmental Protection Agency has established National Ambient Air Quality Standards (NAAQS) for exposure to carbon monoxide (CO) in outdoor air. CO levels in outdoor air must be maintained below 9 ppm over a twenty-four hour period in order to meet this standard (US EPA, 2000). While CO was not detected at levels that exceeded the MDPH action level nor the NAAQS, the fact that it was detected in some areas may indicate that the mechanical exhaust is not working optimally or that pathways exist allowing emissions to enter the occupied space.

As mentioned previously, the station is equipped with a mechanical exhaust system to remove exhaust from the engine bay during vehicle idling. The system in use at the station connects directly to the tail pipe of the engine via a pressurized cuff (Picture 9). As the vehicle exits the station, the cuff, which is pulled on a runner, trips a trigger releasing the cuff. The system is designed to collect vehicle exhaust directly at the source and remove it from the building, minimizing exposure. Although the engine bay is equipped with local exhaust ventilation, a number of pathways for vehicle exhaust and other pollutants to move from the engine bay into occupied areas on both the first and second floors were identified (Figure 1).

The door to the stairwell (off the engine bay) leading to the upstairs had spaces beneath the door and light could be seen penetrating into the stairwell through this space (Picture 10). Picture 11 shows spaces around the firepole clamshell indicating it does not close tightly.

Another possible pathway for exhaust emissions is through utility holes. The ceiling/walls of the engine bays are penetrated by utility holes. These holes can present potential pathways into occupied areas if they are not airtight. Each of these pathways can allow air to move from the engine bay to occupied areas of the station. In order to explain how engine bay pollutants may be impacting the second floor and adjacent areas, the following concepts concerning heated air and creation of air movement must be understood.

- Heated air will create upward air movement (called the stack effect).
- Cold air moves to hot air, which creates drafts.
- As heated air rises, negative pressure is created, which draws cold air to the equipment creating heat (e.g., vehicle engines).
- Combusted fossil fuels contain heat, gases and particulates that will rise in air. In addition, the more heated air becomes the greater airflow increases.
- The operation of HVAC systems (including rest room exhaust vents) can create negative air pressure, which can draw air and pollutants from the engine bays.

Each of these concepts has influence on the movement of air. As motor vehicles operate indoors, the production of vehicle exhaust in combination with cold air moving from outdoors through open exterior doors into the warmer engine bay can place the bay under positive pressure. Positive pressure within a room will force air and pollutants through spaces around doors, utility pipes and other holes in walls, doors and ceilings. To reduce airflow into the second floor, sealing of these pollutant pathways should be considered.

Other Concerns

WFD staff could not identify the last filter change or preventative maintenance done on the HVAC equipment. BEHA staff inspected AHU filters. The attic AHU filters were bent to fit into their racks (Picture 12). The watch room unit did not have filters installed. In order to decrease aerosolized particulates, properly fitting, disposable filters should be installed in AHUs. The dust spot efficiency is the ability of a filter to remove particulates of a certain diameter from air passing through the filter. Filters that have been determined by ASHRAE to meet its standard for a dust spot efficiency of a minimum of 40 percent would be sufficient to reduce airborne particulates (Thornburg, D., 2000; MEHRC, 1997; ASHRAE, 1992). Note that increased filtration can reduce airflow produced by the univent through increased resistance (called pressure drop). Prior to any increase in filtration, AHUs should be evaluated by a ventilation engineer to ascertain whether they can maintain function with more efficient filters.

A number of exhaust and return vents in common areas and in restrooms had accumulated dust (Picture 2). If exhaust vents are not functioning, backdrafting can occur, which can re-aerosolize dust particles. In addition, these materials can accumulate on flat surfaces (e.g. desktops, shelving and carpets) in occupied areas and subsequently be re-aerosolized, causing further irritation.

Finally, during a perimeter inspection of the building, BEHA staff observed several bees/wasps nests on the exterior of the building and an infestation of bees inside the vent for the hose drying room (Pictures 13 & 14). Dead cockroaches were observed in the stairwell and in the gasket to the refrigerator in the kitchen. Under current Massachusetts law (effective November 1, 2001) the principles of integrated pest management (IPM) must be used to remove pests in state buildings (Mass Act, 2000). Pesticide use indoors can introduce chemicals into the indoor environment that can be sources of eye, nose and throat irritation. The reduction/elimination of pathways/food sources (e.g., crumbs food debris in appliances) that are attracting these insects should be the first step taken to prevent/eliminate this infestation. Although the station is not a state building, the principles of IPM are recommended.

Conclusions/Recommendations

In view of the findings at the time of the visit, the following recommendations are made:

1. Ensure doors around engine bays fit completely flush with threshold. Seal doors on all sides with foam tape, and/or weather-stripping. Consider installing weather-stripping/door sweeps on both sides of doors with access to the engine bay to provide a duel barrier. Ensure tightness of doors by monitoring for light penetration and drafts around doorframes.
2. Replace/repair clamshell around firepoles to prevent pollutant pathways, consider contacting the manufacturer for replacement parts or for advice on how to prevent airflow around poles.
3. Ensure all utility holes are properly sealed in both the engine bay and their terminus to eliminate pollutant paths of migration.
4. Work with Worcester town officials to develop a preventative maintenance program for all HVAC equipment department wide.
5. Change filters for HVAC equipment as per the manufacturer's instructions or more frequently if needed. Ensure filters fit flush in their racks to prevent filter bypass.
6. Continue with plans to transfer local control of HVAC system to WFD staff, ensure staff are properly trained to control the system.
7. To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of building occupancy independent of

thermostat control (excluding engine bay exhaust system). Consider setting thermostat controls to the fan "on" position to provide constant supply and exhaust ventilation.

8. Consider having ventilation systems re-balanced every five years by an HVAC engineering firm.

9. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a HEPA filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

10. Install gutters/downspouts to the junction where the engine bay meets the hose drying room to direct water away from the building. Once repaired, replace any remaining water damaged building materials. Examine the area above and behind these areas for microbial growth. Disinfect areas of water leaks with an appropriate antimicrobial as necessary.

11. Make repairs to windows to eliminate spaces around frames.

12. Clean exhaust and return vents periodically to avoid the build-up of excessive dust.

13. It is highly recommended that the principles of integrated pest management (IPM) be used to rid the building of pest. A copy of the IPM recommendations can be obtained from the Massachusetts Department of Food and Agriculture (MDFA) website at the following website:
http://www.state.ma.us/dfa/pesticides/publications/IPM_kit_for_bldg_mgrs.pdf.

Activities that can be used to eliminate pest infestation may include the following activities.

a) Rinse out recycled food containers. Seal recycled containers in a tight fitting lid to prevent rodent access.

b) Remove any non-food items that rodents are consuming.

c) Stored foods in tight fitting containers.

d) Avoid eating at workstations. In areas were food is consumed, periodic vacuuming to remove crumbs is recommended.

e) Regularly clean crumbs and other food residues from ovens, toasters, microwaves, coffee pots and other food preparation equipment.

12. For further building-wide evaluations and advice on maintaining public buildings, see the resource manual and other related indoor air quality documents located on the MDPH's website at http://www.state.ma.us/dph/beha/iaq/iaqhome.htm.

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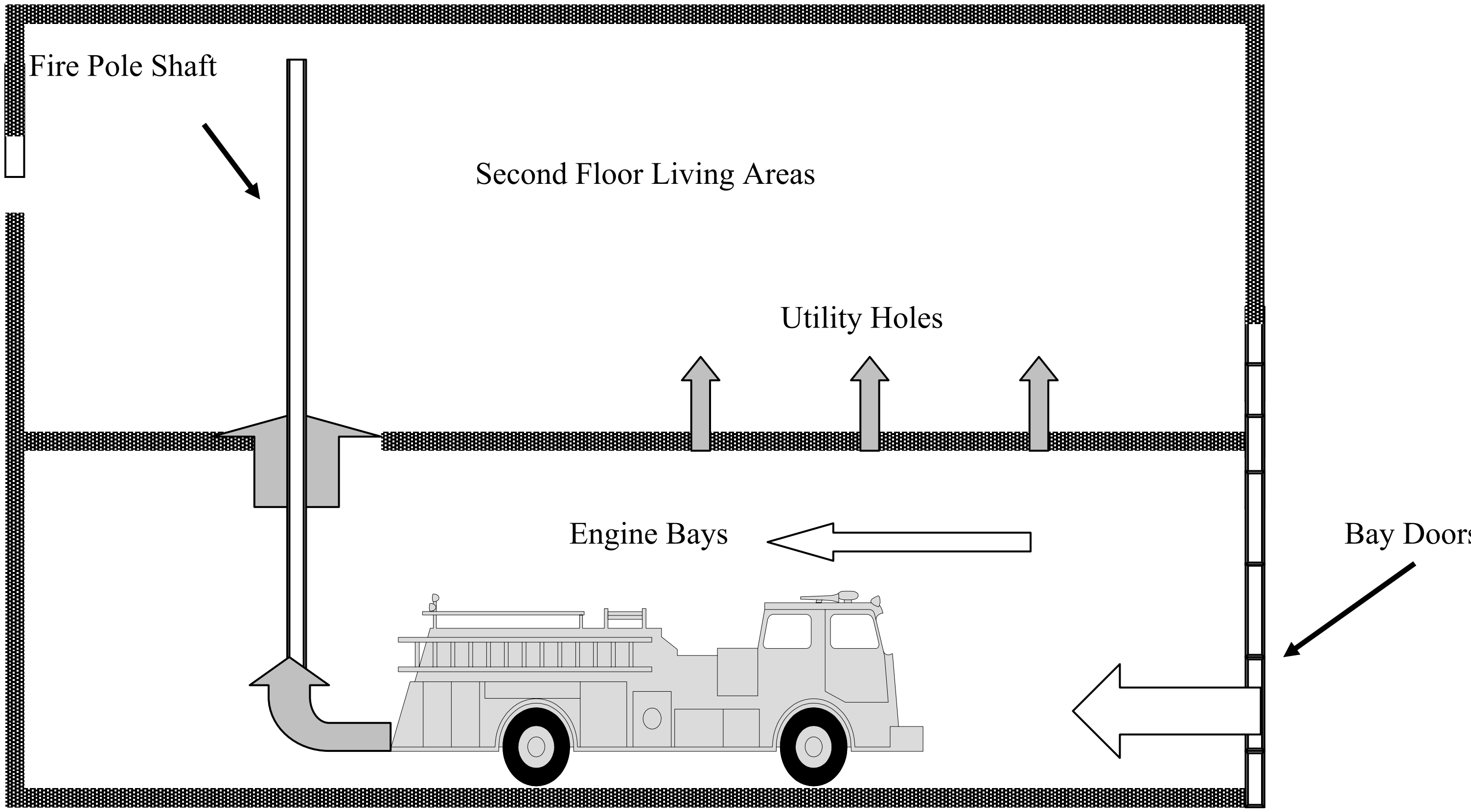
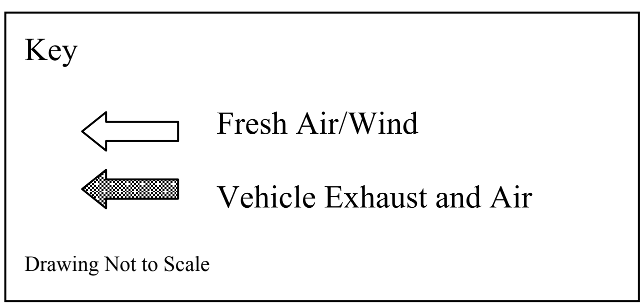
Figure 1 **Potential Pathways of Air and Pollutant Movement from Engine Bays into Occupied Areas***



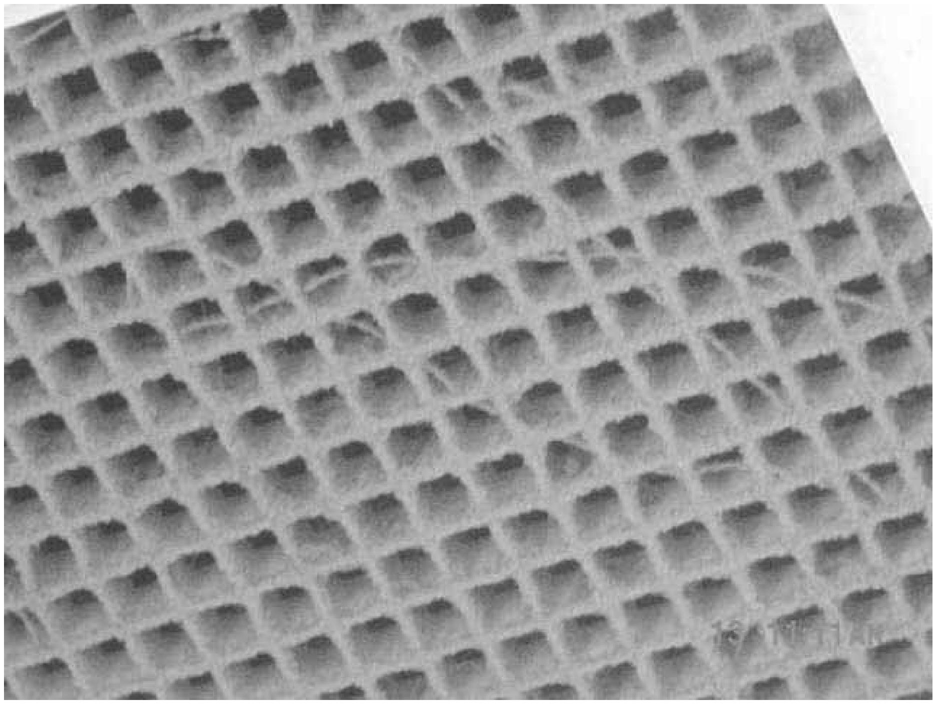
* Note exhaust is minimized via the vehicle exhaust ventilation system



Picture 1

Ceiling-Mounted Supply Vent

Picture 2



Ceiling-Mounted Return Vent, Note Dust and Cobweb Accumulation on Vent

Picture 3

Fan Setting on Right in "Auto" Position

Picture 4

Water Damage, Peeling Paint and Efflorescence

Picture 5

Water Damaged Ceiling Tiles

Picture 6

Junction/Seam between the Engine Bay and Hose Drying Room Note Dark Stain at Seam Indicating Water Damage

Picture 7

Close-up of Water Damage Shown in Preceding Picture Light Stains Indicate Moss Growth

Picture 8

Spaces around Window Frames on Second Floor, Pen Inserted to Show Width

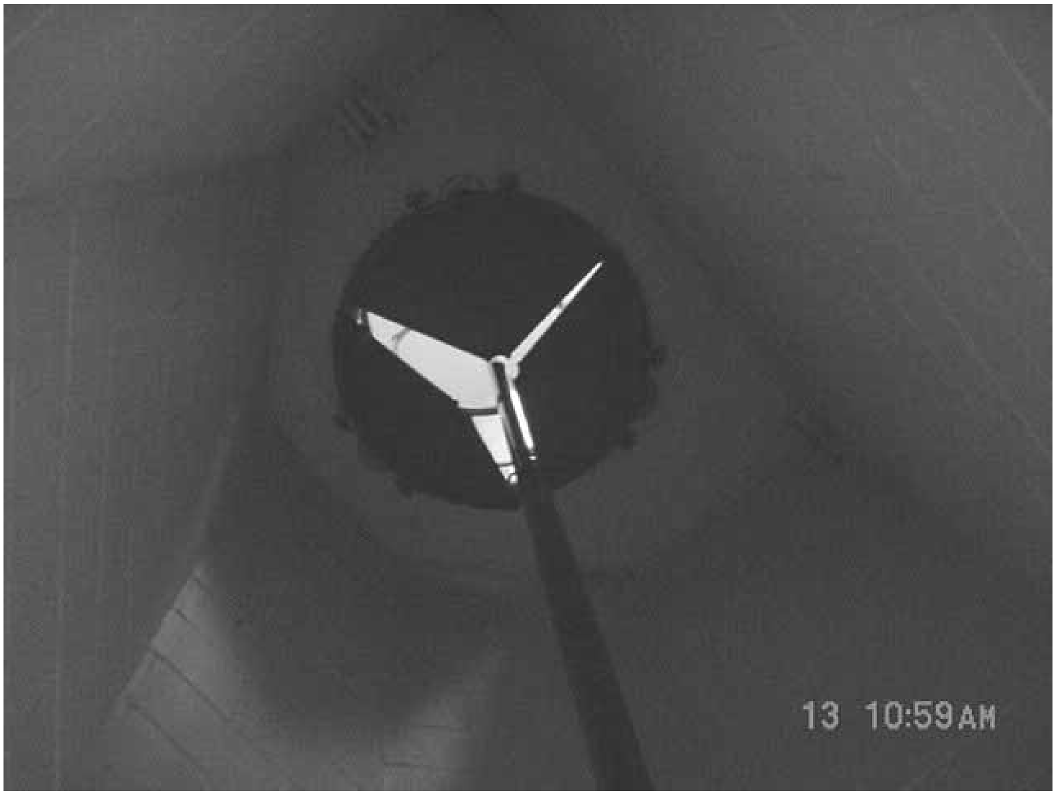
Picture 9

Vehicle Exhaust System Attached to Exhaust Pipe

Picture 10

Light Penetrating beneath Engine Bay Door

Picture 11



Light Penetrating around Fire Pole Clamshell

Picture 12

Attic AHU Filters Bent to Fit in Unit

Picture 13

Bee/Wasp Infestation in Vent to the Hose Drying Room

Picture 14

Bee/Wasp's Nests on Exterior of the Building

TABLE 1

Indoor Air Test Results – McKeon Road Fire Station, Worcester, MA August 13, 2003

Location	Carbon Dioxide *ppm	Carbon Monoxide *ppm	Temp °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
							Intake	Exhaust	
Background	405	0-2	78	84					
Perimeter Notes									Bees/wasp nests in air intake, on exterior walls, water damage algae on exterior walls-no gutter/downspout at junction
Coat Room	434	2	77	51	0	N	Y	Y	1 CT
Laundry Room						N	N	N	
Storage Room (near boiler room)						N	N	N	1 CT, historic WD
Engine Bay	473	2	78	61	2	N	Y	Y	Spaces beneath engine bay door, local vehicle exhaust ventilation system
Hose Drying Room						N	Y	Y	
Foyer Entrance	451	2	75	57	0	Y	Y	Y	Return vents dirty
Watch Room	527	0	72	61	0	Y	Y	Y	2 CT, historic leak AHU

*** ppm = parts per million parts of air**
CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

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Location	Carbon Dioxide *ppm	Carbon Monoxide *ppm	Temp °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation Intake	Ventilation Exhaust	Remarks
Hallway		0				N	N	N	Electric heater, clogged dirty filter
Stairwell		0				N	N	N	Spaces under door, cockroach
Day Room	420	0	70	65	1	Y	Y	Y	Efflorescence/peeling paint corner, WD
Computer Room	471	0	72	67	1	Y	Y	Y	CT ajar
TV Room	448	0	72	65	0	Y	Y	Y	Large gap around window frame
Engine 15 Bunk Room	400	0	71	64	0	Y	Y	Y	
Center Bunk Room	410	0	71	64	0	Y	Y	Y	
Hallway									1 CT
Engine 15 Capt. Ford	409	1	73	64	0	Y	Y	Y	AC system not operating
Rescue Officer's Room	408	0	72	64	0	Y	Y	Y	
Main Locker Room	424	0	71	63	1	N	Y	Y	

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